

POLYDORA AND RELATED GENERA (POLYCHAETA, SPIONIDAE) AROUND PUERTO MONTT AND CHILOÉ ISLAND (CHILE), WITH DESCRIPTION OF A NEW SPECIES OF *DIPOLYDORA*

Waka Sato-Okoshi and Masashi Takatsuka

ABSTRACT

A total of seven species of spionid polychaetes including one new species *Dipolydora huelma* were found from Puerto Montt and Chiloé Island (Chile). *Polydora* cf. *rickettsi*, *Dipolydora huelma* sp. nov. and *D. giardi* were extracted from self-excavated burrows in calcareous substrata: mollusc shells and coralline alga. *Dipolydora socialis*, *Boccardia wellingtonensis*, *B. chilensis* and *B. tricuspa* were found from mud, sand and sandstone intertidal flats. *Boccardia wellingtonensis* was re-examined, and Chilean specimens of *B. polybranchia* were re-examined and suggested that they may belong to *B. wellingtonensis*. Morphological variation, habitat, boring and crawling activity, ecology, reproduction and development, and burrow structure of each species is described and discussed.

Polydora and related genera belonging to spionid polychaetes (so called polydorid species) are found in a wide variety of habitats, from soft sediments to hard calcareous materials (Blake, 1996). However, they often show species-specific habitat preferences (Sato-Okoshi, 1999, 2000). Although polydorid species include non-boring species, some of them are widely known for their boring activities in mollusc shells, corals, coralline algae and barnacles (Blake and Evans, 1973; Sato-Okoshi and Okoshi, 1997; Martin and Britayev, 1998; Sato-Okoshi, 1999). Particularly, they have been reported as borers of commercially important molluscs and their effects on their hosts have been studied from the viewpoint of molluscan aquaculture (Kent, 1979; Mori et al., 1985; Okoshi and Sato-Okoshi, 1996; Handley, 1998).

Los Lagos, the Tenth Region of Chile, supports an increasing development of molluscan aquaculture. Important species in aquaculture in this region are oysters (*Ostrea chilensis*, *Crassostrea gigas*), scallop (*Argopecten purpuratus*) and mussels (*Aulacomya ater*, *Choromytilus chorus*, *Mytilus chilensis*). As it occurs worldwide, several polydorids were observed to bore into the shells of these molluscs. In this study, we had the opportunity to survey these species, together with other boring (i.e., from shells of non-cultured molluscs and other calcareous substrata) and non-boring polydorids inhabiting the regions of Puerto Montt and Chiloé Island, Chile (41–43°S, 72–74°W).

Nearly all previous descriptions or reports of polydorids from Chile are based on samples collected from subtropical or subantarctic seas (Blake and Woodwick, 1971; Blake, 1979, 1983; Rozbaczylo, 1985; Cañete, 1988; Basilio et al., 1995). Our study area belongs to a temperate region. Thus, the data reported herein contribute to the increase of knowledge of the Chilean polydorids. Special attention is addressed to describe the morphological variability of the Chilean species reported herein, as well as to define their habitat, boring and crawling ability, ecology, reproduction and burrow structure. Moreover, *Boccardia wellingtonensis* (a previously known non-boring species inhabiting mud, sand or sandstone flats) is re-examined based on the specimens collected during the present survey and *Dipolydora huelma* sp. nov. (a boring species inhabiting self-excavated burrows in calcareous substrata) is newly described.

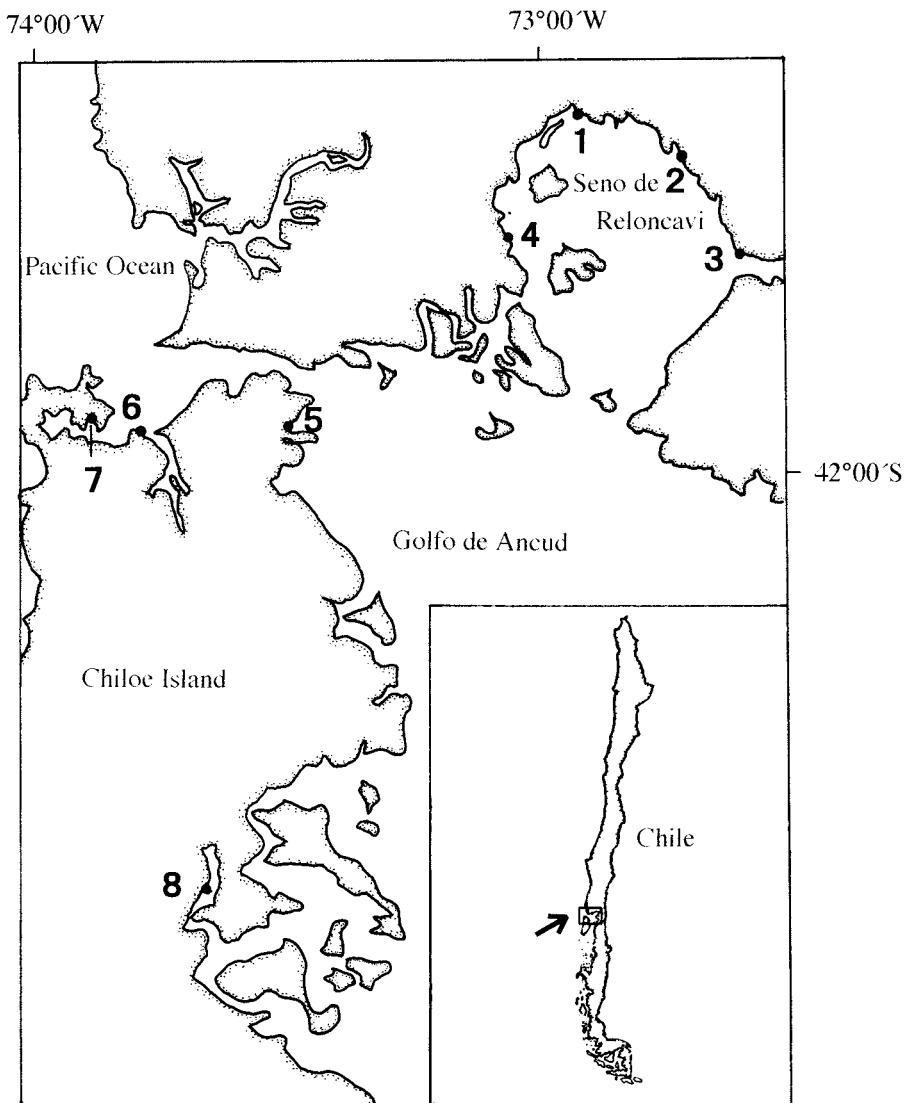


Figure 1. Sampling sites in Puerto Montt and Chiloé Island, Tenth Region, Chile. 1. Puerto Montt. 2. Quillaipe. 3. La Arena. 4. Huelmo. 5. Hueihue. 6. Ancud. 7. Pullinque. 8. Castro.

MATERIAL AND METHODS

Polydora, *Dipolydora* and *Boccardia* species were collected at eight sites around Puerto Montt and Chiloé Island, Chile in February and March 1998 (Fig. 1). Boring species were extracted from the shells of both natural and cultured molluscs (*O. chilensis*, *C. gigas*, *A. purpuratus*, *Crepidula* sp., *Tegula atra*, *Fissurella nigra*) and a coralline alga (*Lithothamnium* sp.). Cultured molluscs of *O. chilensis*, *C. gigas* and *A. purpuratus* were obtained at a depth of 5–12 m from protected environments of Chiloé Island. *O. chilensis*, *C. gigas* and *A. purpuratus* were obtained at a depth of 5 m in

Table 1. Boring species of *Polydora* and *Dipolydora* from calcareous substrata in Puerto Montt and Chiloé Island, Chile (C = cultured, N = natural).

Species	Host	Locality
<i>Polydora</i> cf. <i>rickettsi</i>	<i>Ostrea chilensis</i> ^C	Pullinque, Spat originally from Ancud and cultured in Hueihue
	Between <i>Ostrea chilensis</i> ^C and spat collector (scallop shell)	Hueihue
	<i>Ostrea chilensis</i> ^N	Pullinque, Castro
	<i>Crassostrea gigas</i> ^C	Pullinque
	<i>Argopecten purpuratus</i> ^C	Pullinque
	<i>Crepidula</i> sp. ^N	Pullinque, Quillaipe
	<i>Tegula atra</i> ^N	Pullinque, Quillaipe
	<i>Fissurella nigra</i> ^N	Pullinque, Quillaipe
	<i>Crepidula</i> sp. ^N	Huelmo, Quillaipe
	Between <i>Ostrea chilensis</i> ^C and spat collector (scallop shell)	Hueihue
<i>Dipolydora huelma</i>	<i>Crassostrea gigas</i> ^C	Pullinque
	<i>Argopecten purpuratus</i> ^C	Pullinque
	<i>Crepidula</i> sp. ^N	Huelmo
	<i>Lithothamnium</i> sp. ^N	Huelmo
<i>Dipolydora giardi</i>		

Pullinque, and *O. chilensis* at a depth of 10–12 m in Hueihue. Natural molluscs were collected from the intertidal rocky shore.

Palp activity was examined by observing the beating frequency and strength under still sea water before removing from their original habitats. Then, worms were extracted by fracturing the shells and coralline algae with cutting pliers and a hammer. Non-boring species were obtained from the intertidal zone by cracking sand deposits and sandstone with a hammer and hands or sieving sand and mud through a mesh sieve.

After the worms were removed from their habitats, observations were made on ability to crawl, morphological characteristics, state of sexual maturity, and presence and conditions of the egg-capsules for each species. Then specimens were fixed with 10% formalin-sea water mixture. The structure of the burrows was investigated using a soft x-ray analyzer (SOFTEX-EMB, Tohoku University).

Specimens were deposited in Natural History Museum and Institute, Chiba (CBM) and National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM).

RESULTS

BORING SPECIES

Three species, *Polydora* cf. *rickettsi*, *Dipolydora huelma* sp. nov. and *D. giardi*, were found to inhabit self-excavated burrows in different calcareous substrata (Table 1).

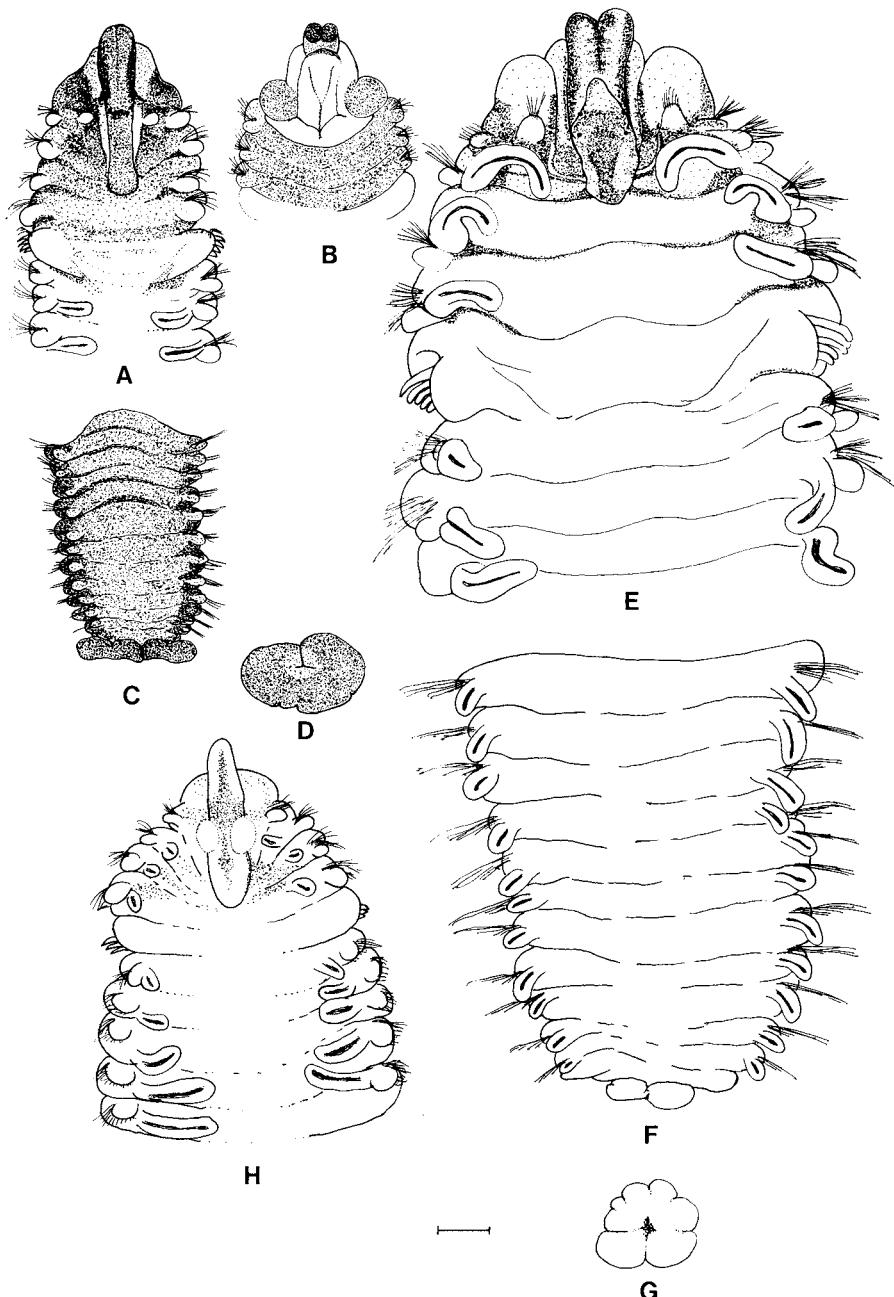


Figure 2. *Polydora* cf. *rickettsi* Woodwick. A, anterior end without palps, dorsal view of the dark pigmented specimen which inhabits tidal pool in Pullinque; B, anterior end, ventral view of the same specimen as in A; C, posterior end, dorsal view of the same specimen as in A; D, pygidium of the same specimen as in A. *Boccardia chilensis* Blake & Woodwick. E, anterior end without palps, dorsal view; F, posterior end, dorsal view; G, pygidium. *Boccardia tricuspa* (Hartman). H, anterior end without palps, dorsal view. Scale bar 0.2 mm.

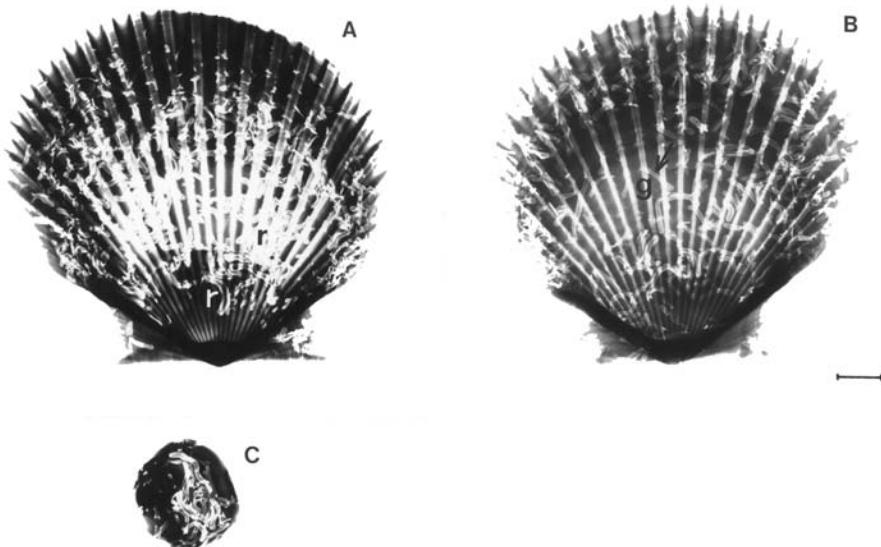


Figure 3. Soft x-ray photographs of burrows of *Polydora* cf. *rickettsi* (r) and *Dipolydora giardi* (g) in cultured *Argopecten purpuratus* (A, left valve; B, right valve) and natural *Crepidula* sp. (C) shells in Pullinque. Scale bar 10 mm.

Genus *Polydora* Bosc, 1802

Polydora cf. *rickettsi* Woodwick, 1961
(Figs. 2A-D)

Morphology of New Material.—Up to 20 mm long, 0.95 mm wide at setiger 5, for 125 setigers. Color in life tan.

Prostomium weakly incised, curved downward anteriorly. Caruncle extending to near end of setiger 3 to end of 4, once swollen in setiger 1-2; eyes absent or present, up to 4 arranged in trapezoid. Palps transparent with dark pigmentation along edge. Body pigmentation variable- without pigmentation or dark pigmentation on palp, prostomium, peristomium, setigers 1-4 on dorsal side, setigers 1-3 on ventral side, and posterior setigers. Branchiae present from setiger 7, continuing for four-fifths of body, overlapping in middle. Setiger 1 without notosetae. Setigers 2-4 with winged capillary neuro- and notosetae.

Heavy spines of setiger 5 falcate with lateral tooth, spines numbering 4-5, spines alternating with pennoned companion setae; dorsal and ventral setae present. Bidentate hooded hooks replacing winged capillary neurosetae from setiger 7, with up to nine hooks per fascicle, decreasing to about two hooks per fascicle posteriorly. Hooks with constriction on shaft and main fang at right angle to shaft. No special posterior notosetae.

Pygidium a flaring disc, dorsally open.

Habitat and Ecology.—*P. cf. rickettsi* excavated burrows in living shells of both natural and cultured molluscs. It was one of the most common boring species around Puerto Montt and Chiloé Island. More than 50 worms were observed to bore into one valve of *O. chilensis* and *C. gigas*, and more than 100 worms into one valve of *A. purpuratus* cultured at a depth of 5 m in Pullinque, Chiloé Island (Figs. 3A,B). Worms were observed to bore

initially randomly between growth squamae all over the oyster shell surface, and were observed to bore initially randomly between ribs, in the concave region, on the scallop shell. Long mud tubes were observed to protrude from the burrows. A large number of worms were observed to bore into the natural molluscs inhabiting tidal pool in Pullinque (Fig. 3C). As compared to this, only few worms were extracted per shell in the natural molluscs inhabiting intertidal zone except in Pullinque. No crawling activity was observed after the worm was removed from the shell. It was incapable of either crawling or of burrowing in mud deposits or in the crevices of calcareous substrata. Palp activity was weak, with palps just protruding from the burrow opening, and beating slowly. Many worms disappeared from the shells in the field in late March which suggested a completion of the life span at this season.

Reproduction and Development.—Many egg strings were found in burrows in February in Pullinque. Approximately 10–15 capsules in one string; 30–80 fertilized eggs of 90–100 μm in diameter were observed in each capsule. The diameter of morula was 100–120 μm . No nurse eggs were observed, all embryos developed simultaneously, and they hatched as 3-setiger larvae measuring 280 μm long. The length of the capsule was 300–400 μm each. Planktonic forms occurred mainly from March to May. They remained planktonic until the 16–17 setiger larvae measured 1000 μm . A few 20–23 setiger juveniles were obtained in February and many 16–21 setiger juveniles were obtained in May from the field.

Burrow Structure.—*P. cf. rickettsi* excavated a typical U-shaped burrow (Fig. 3). The burrow was wider than that of *Dipolydora giardi*.

Remarks.—Some morphological characteristics differ from the descriptions by Woodwick (1961) and Blake (1983). The prostomium was described as round, whereas the present specimens seem to have a prostomium dorsally round and ventrally weakly incised with its end curved downward. The caruncle extends to the end of setiger 4 in large specimens but extends only to near the end of setiger 3 in small ones from Puerto Montt and Chiloé Island. Eyes are absent or present in Chilean specimens. Body pigmentation is remarkably variable: while populations inhabiting natural molluscs in tidal pools had dense black pigmentation on both anterior and posterior setigers, the population inhabiting cultured molluscs in the subtidal zone either lacked pigmentation or were weakly pigmented. Instead of heavy musculature on setiger 5, and setiger 5 overlapping setigers 6–7 as described by Woodwick (1961), setiger 5 only overlaped maximally setiger 6 in the present specimens. Further investigation is needed to determine whether the specimens from lower California and Mexico (collected from the tubes of *Spirobranchus incrassatus*) and Montemar, Chile (collected from the shell of *Concholepis concholepis*) and those from Puerto Montt and Chiloé Island are the same species based on morphological, ecological and other characteristics.

Distribution.—Puerto Montt and Chiloé Island, Chile.

Dipolydora Verrill, 1879
Dipolydora huelma new species
(Figs. 4,5)

Description.—Length 18 mm, width 1.0 mm at setiger 5, for 135 setigers. Color in life tan. Palps transparent with brown pigmentation along edge. Slight dark pigmentation on dorso-lateral side of posterior setigers.

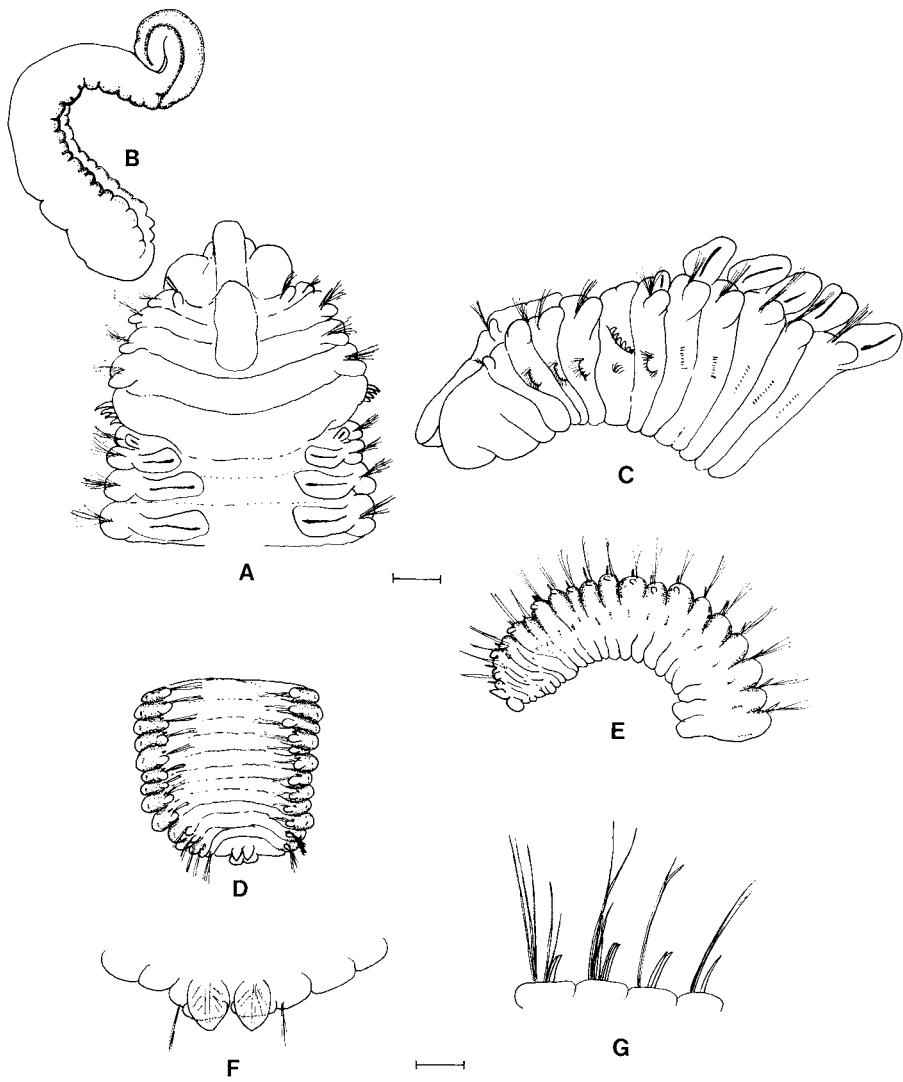


Figure 4. *Dipolydora huelma* sp. nov. (Holotype). A, anterior end without palps, dorsal view; B, palp; C, anterior end, lateral view; D, posterior end, dorsal view; E, posterior end, lateral view; F, pygidium, dorsal view; G, posterior setigers with capillaries and special spines, lateral view. Scale bar 0.2 mm for A–E, 0.1 mm for F–G.

Prostomium anteriorly rounded, caruncle extending to middle of setiger 3, eyes absent. Very small branchiae first appearing on setiger 6, becoming larger from setiger 7, wide in anterior setigers, then gradually becoming slender. Branchiae continuing to middle of body, absent from posterior half. Setiger 1 with both noto- and neurosetae. Setigers 2–4 with fascicles of winged capillaries in both rami, from setiger 6 long winged capillary notosetae present, neuropodia of setiger 6 bearing capillaries only. Neuropodial bidentate hooded hooks first appearing from setiger 7, accompanying 1–2 capillaries in setigers 7–8 and in posterior setigers. Hooks without constriction on shaft, main fang at obtuse angle

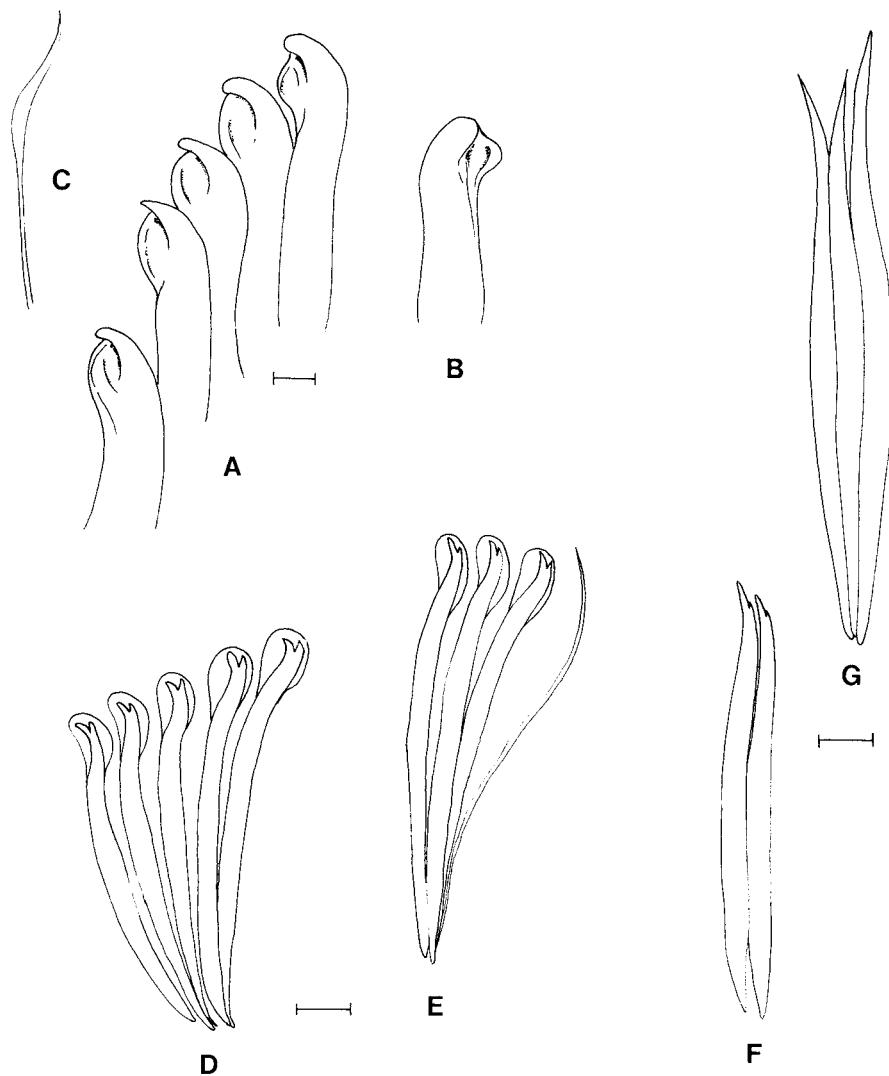


Figure 5. *Dipolydora huelma* sp. nov. (Paratype). A, modified spines of setiger 5; B, worn modified spine of setiger 5; C, companion seta of setiger 5; D, bidentate hooded hooks of middle setiger; E, bidentate hooded hooks of posterior setiger with capillary seta; F, non-hooded hooks of post-posterior setiger; G, notopodial spines of posterior setiger. Scale bar 0.01 mm for A–C, 0.02 mm for D–G.

to shaft, and only slight angle between teeth. Hooks numbering 8–9 per fascicle in middle setigers, gradually diminishing in number to two in posterior setigers. Hooks without hoods in far posterior setigers, hook with reduced angle between teeth and without accompanying capillaries. Long winged posterior notosetae present almost to end of body accompanying 1–3 large curved aciculæ spines.

Setiger 5 modified, heavy spines numbering six, falcate with large prominent accessory flange, major spines alternating with pennoned companion setae; dorsal setae absent, short winged capillary ventral setae present.

Pygidium reduced, formed of four small lobes, dorsal pair longer and ventral pair shorter and wider.

Variation.—Up to 1.0 mm wide at setiger 5, for 135 setigers. Specimens with or without slight dark pigmentation on dorso-lateral side of posterior setigers. Bidentate hooded hooks first present from setiger 7 accompanied by 1–2 capillaries in setigers 7–9.

Habitat and Ecology.—*D. huelma* excavated burrows in living shells of natural populations of *Crepidula* sp. from intertidal zones. This species was not extracted from the cultured molluscs in Pullinque in which a large number of worms of two other boring species inhabited. It was not common around Puerto Montt and Chiloé Island. Very little crawling activity was observed after removal from the shell and the worm was incapable of either forming a new burrow or hiding itself in mud deposits. Palp activity was weak. Palps were observed just protruding from the burrow and beating very slowly.

Reproduction and Development.—Gametocytes were observed in the coelom and egg strings were found in burrows in February in Huelmo. Oocytes measured 100 µm in diameter. No nurse eggs were observed and all embryos developed simultaneously in the capsule until hatching as 3-setiger larvae measuring 250–270 µm long.

Burrow Structure.—*D. huelma* excavated a U-shaped burrow, the bottom of which was enlarged horizontally.

Remarks.—*D. huelma* resembles *D. antonbruunae* Blake collected from the gastropod shells from Peru (Blake, 1983). Both species possess curved acicular spines in posterior notopodia, a large flange on the modified spine of setiger 5 and branchiae beginning from setiger 6. However, *D. huelma* has a rounded prostomium, the peristomium is not truncate, branchiae always begin from setiger 6, it possesses 1–3 acicular spines with about six long unilimbate capillaries per posterior notopodium, and the pygidium is formed of four small lobes with dorsal pair longer and ventral pair shorter. Conversely *D. antonbruunae* has a pointed prostomium, the peristomium is truncate, branchiae begin from setiger 7 and rarely from setiger 6, about 1–2 acicular spines and 4–5 unilimbate capillaries per posterior notopodium, and the pygidium is formed of four small lobes with dorsal pair smaller. *Dipolydora huelma* is larger than *D. antonbruunae*, the latter measuring up to 8.5 mm long, 0.4 mm wide, for 90 setigers. Moreover, *D. antonbruunae* is distributed in tropical seas (Peru, 10°S, by Blake, 1983), whereas *D. huelma* occurs in temperate seas.

Etymology.—The specific name *huelma* is derived from the geographical name Huelmo from where the species was first discovered.

Type Series.—Holotype (CBM-ZW 941) and paratypes (CBM-ZW 942) extracted from the shells of *Crepidula* sp. from Huelmo, Tenth Region, Chile, collected on 24 February 1998 by W. Sato-Okoshi and M. Takatsuka. Paratypes (CBM-ZW 943) extracted from the shells of *Crepidula* sp. from Quillaipe, Tenth Region, Chile, collected on 24 February 1998 by W. Sato-Okoshi and M. Takatsuka.

Distribution.—Known only from the type locality.

Dipolydora giardi (Mesnil, 1896)

Polydora giardi Mesnil, 1896: 195–202. Blake, 1983: 262. Sato-Okoshi and Okoshi, 1997: 484.
Dipolydora giardi: Blake, 1996: 186–188. Sato-Okoshi, 1999.

Morphology of New Material.—Up to 8 mm long, 0.45 mm wide at setiger 5, for 80 setigers. Color in life light tan, without pigmentation. Eyes absent. Caruncle extending to end of setiger 3 in all specimens. Long unilimbate and short regular capillary setae coexist in posterior notopodia. Pygidium disc-like with one large ventral lobe and two small dorsal ones, occasionally the three lobes continuous and inconspicuous.

Habitat and Ecology.—*D. giardi* inhabited intertidal and subtidal coralline algae and mollusc shells. It was one of the most common boring species around sampling area. A large number of *D. giardi* were observed to bore into the shells of cultured molluscs in Pullinque (Fig. 3A,B). Very low crawling activity was observed after being removed from the shell and the worm was incapable of burrowing into mud deposits. Palp activity was weak, beating slowly.

Reproduction and Development.—Many egg strings were found in burrows in February at Pullinque. All embryos developed simultaneously and hatched as 3-setiger larvae. Thirty to 40 embryos occur in each capsule; the diameter of the morula was 90–100 μm ; the length of the capsule was 300–400 μm .

Burrow Structure.—*D. giardi* formed a narrow U-shaped burrow (Fig. 3).

Remarks.—The specimens from Puerto Montt and Chiloé Island match the morphological descriptions of specimens from South America (Blake, 1983), from Vancouver Island (Sato-Okoshi and Okoshi, 1997) and from Japan (Sato-Okoshi, 1999).

Distribution.—Cosmopolitan in calcareous substrata.

NON-BORING SPECIES

Four species, *Dipolydora socialis*, *Boccardia wellingtonensis*, *B. chilensis*, and *B. tricuspa*, were found to inhabit mud, sand and sandstone intertidal flats, and mud deposits in shell crevices and coralline algae (Table 2).

Dipolydora Verrill, 1879*Dipolydora socialis* (Schmarda, 1861)

Polydora socialis: Blake, 1971: 20–23; 1983: 264. Blake and Kudenov, 1978: 248–250. Sato-Okoshi & Okoshi, 1997: 486.

Dipolydora socialis: Blake, 1996: 189–192.

Morphology of New Material.—Up to 25 mm long, 1.1 mm wide at setiger 5, for 120 setigers. Color in life light tan. Slight dark pigmentation on and along caruncle, some specimens with black broken transverse lines on dorsal side of anterior setigers. Caruncle extends to end of setiger 7–9, larger worms with longer caruncle; branchiae beginning from setiger 8 and extends to near posterior end.

Habitat and Ecology.—*D. socialis* inhabited mud deposits within the crevices of the shells of cultured *Ostrea chilensis*. It was also found between a spat collecting shell and a sessile cultured *O. chilensis* shell, and a shallow groove without a clear burrow was found

Table 2. Non-boring species of *Dipolydora* and *Boccardia* in Puerto Montt and Chiloé Island, Chile (C = cultured).

Species	Habitat	Locality
<i>Dipolydora socialis</i>	Mud in crevices of <i>Ostrea chilensis</i> ^C shells	Pullinque
	Mud in crevices between <i>Ostrea chilensis</i> ^C shells and spat collectors (scallop shell)	Hueihue
<i>Boccardia wellingtonensis</i>	U-shaped burrows in mud, sand and sandstone flats	Puerto Montt, Huelmo, Pullinque
	Mud and sand deposits in tidal pool	Puerto Montt, La Arena, Huelmo
	Mud and sand flats without burrows	Puerto Montt, Huelmo, Pullinque
<i>Boccardia chilensis</i>	Coralline alga <i>Lithothamnium</i> sp.	Huelmo
<i>Boccardia tricuspa</i>	Mud and sand flats	Puerto Montt

under the worm. No crawling activity was observed after removal from the shell. Palp activity was weak with slow beating.

Reproduction.—Gametocytes were present in all individuals in February. No egg capsules were observed.

Remarks.—Specimens from Puerto Montt and Chiloé Island agree with the descriptions from North America (Blake, 1971, 1996; Sato-Okoshi and Okoshi, 1997) and from Australia (Blake and Kudenov, 1979).

Distribution.—East, west and gulf coasts of North America; east and west coasts of South America; Australia; New Zealand; Japan.

Boccardia Carazzi, 1893

Boccardia wellingtonensis Read, 1975

(Fig. 6)

Boccardia wellingtonensis Read, 1975: 404–406.

Morphology of New Material.—Up to 18 mm long, 1.4 mm wide at setiger 5, for 85 setigers. Color in life tan. Black pigmentation on midline groove of caruncle, along both sides of caruncle, and until dorsal side of setigers 6–12. Palps with dark brown pigmentation along the edge.

Prostomium anteriorly bilobed, caruncle extending to end of setiger 1 or middle of setiger 2; eyes 2–6, up to three pairs arranged in trapezoid. Branchiae on setigers 2,3,4, ,6 and subsequent setigers continuing to posterior one-fourth of body, branchiae long and slim, longest at setigers 9–11, overlapping in middle. Setiger 1 with small notopodia lacking notosetae. Notosetae on setigers 2–4 arranged in three rows: anterior curved, shorter setae, posterior fewer in numbers and longer setae, and middle setae. Neurosetae of setigers 1–4 arranged in two rows.

Setiger 5 modified, bearing two types of modified spines arranged in two rows: (1) ventral row with up to five bristle topped spines, (2) dorsal row with up to four simple, falcate spines without bristles; companion setae absent. Ventral fascicle with up to eight winged setae of setiger 5 present, dorsal fascicle absent.

Bidentate hooded hooks replace winged capillary neurosetae from setiger 7; nine hooks per fascicle in middle setigers, decreasing to one posteriorly; hooks without constriction

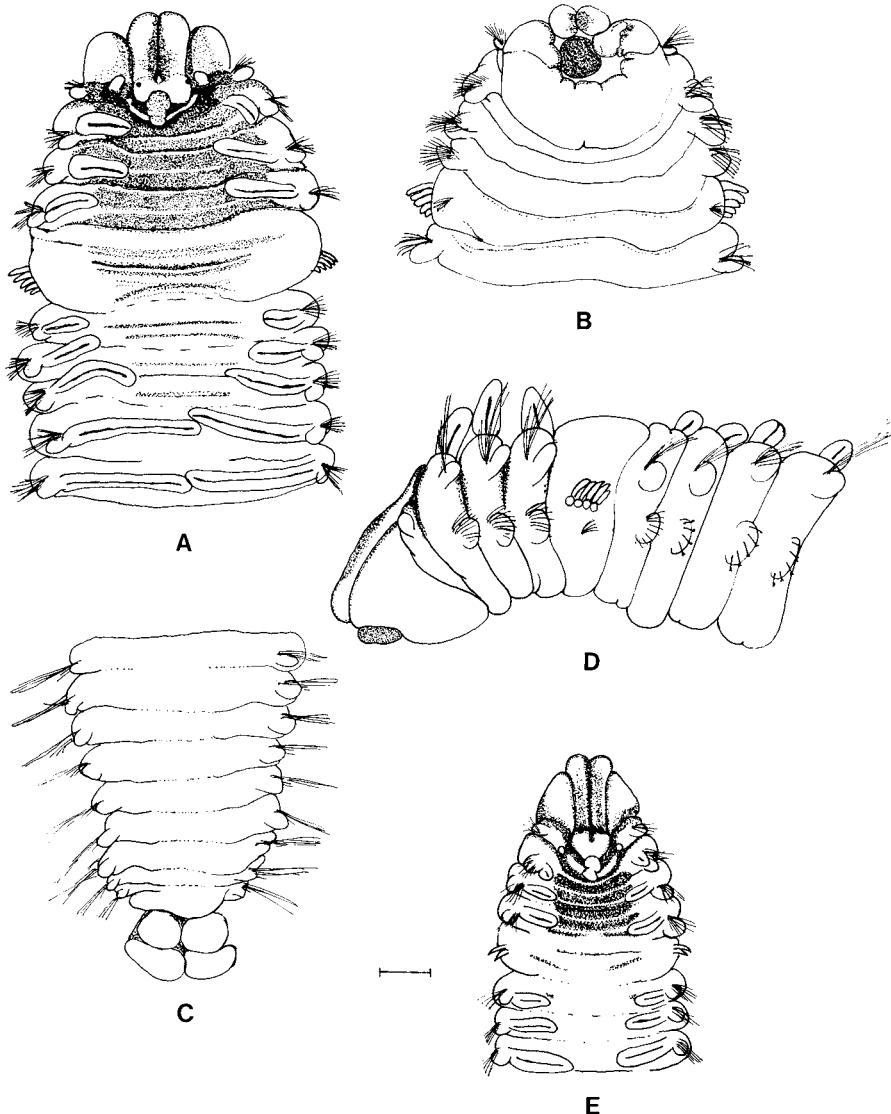


Figure 6. *Boccardia wellingtonensis* Read. A, anterior end without palps, dorsal view of the large specimen; B, anterior end, ventral view of the same specimen as in A; C, posterior end, dorsal view of the same specimen as in A; D, anterior end, lateral view of the same specimen as in A; E, anterior end without palps, dorsal view of the small specimen. Scale bar 0.2 mm.

on shaft and with main fang at right angle to shaft; accompanied by up to four capillary setae, in setigers 7 up to 11 (most specimens in setigers 7–9). Only long and short unilimbate capillary notosetae present in posterior setigers, special notosetae absent.

Pygidium divided into four lobes, dorsal pair slightly smaller than ventral pair, some specimens without clear lateral incision separating dorsal and ventral pairs.

Habitat and Ecology.—*B. wellingtonensis* was very abundant around Puerto Montt and Chiloé Island, recording population densities of approximately 20,000 ind m^{-2} in mud, sand and sandstone intertidal flats. *B. wellingtonensis* excavated U-shaped burrows in sandstone flats, projecting their palps from one burrow opening. High crawling activity was observed after removing the worms from their burrows. The worm was capable of hiding itself in mud deposits. Palp activity was high, beating fast and strong.

Reproduction and Development.—Many egg strings were found in February. Six to 13 egg capsules occurred in a single string, with each capsule containing 30 to 60 eggs and larvae. Two different stages of larvae and many nurse eggs coexisted in a single capsule (e.g., two 8–9 setiger larvae, two 6 setiger larvae and many nurse eggs/capsule; two 10 setiger larvae, three 6 setiger larvae and nurse eggs/capsule). Fertilized egg and nurse egg measured 130–150 μm , 2–3 setiger larvae 200 μm long, 6 setiger larvae 400 μm , 8–9 setiger larvae 700 μm , and 10 setiger larvae 750 μm . There was one black spot on dorsal side of each setiger from setiger 3 in all larvae.

Remarks.—*B. wellingtonensis* Read, 1975 was originally described from New Zealand and was synonymized to *B. polybranchia* (Haswell, 1885), so called a cosmopolitan species, by Blake (1983) based on the redescription by Blake and Kudenov (1978). The morphological, habitat and developmental characteristics of the specimens obtained around Puerto Montt and Chiloé Island very well matched the original description of *B. wellingtonensis*. Type materials of *B. wellingtonensis* from New Zealand (deposited in the Museum of New Zealand) and Chilean specimens of *B. polybranchia* (from the Smithsonian Institute) were examined. The morphological differences for all studied populations are summarized in Tables 3 and 4.

The Chilean specimens of *B. wellingtonensis* here examined match the original description by Read (1975) except for the presence of notopodia on setiger 1 in the former. However, a re-examination of the type specimens of *B. wellingtonensis* revealed that a small inconspicuous notopodia is present in all specimens. Moreover, habitat, burrow morphology and larval development pattern (lecithotrophy, adelphophagy) are similar in New Zealand and Chilean populations. Conversely, major differences between the two species occur in the caruncle size and the number of hooded hooks per fascicle (Tables 3,4). Although caruncle length is often considered a non species-specific, size dependent character, Blake and Kudenov (1978) report specimens of *B. polybranchia* with longer caruncles, despite fitting the same size-range. Similarly, they had a higher maximum number of hooded hooks per fascicle. Taking into account all these observations and the abundance of the populations herein reported, we conclude that the specimens from Puerto Montt and Chiloé Island as well as the Chilean specimens of *B. polybranchia* (sensu Blake 1983) belong to *B. wellingtonensis*.

Distribution.—New Zealand, Chile.

Boccardia chilensis Blake and Woodwick, 1971
(Figs. 2E–G)

Boccardia chilensis Blake and Woodwick, 1971: 36–37. Read, 1975: 398–399. Blake and Kudenov, 1978: 238–240. Blake, 1983: 244–246.

Morphology of New Material.—Up to 20 mm long, 1.4 mm wide at setiger 5, for 105 setigers. Color in life tan, greenish black on prostomium, peristomium, dorsal side of

Table 3. Morphological characteristics of *Boccardia wellingtonensis* Read, 1975 from New Zealand, and *B. wellingtonensis* from Chile (this study).

	<i>B. wellingtonensis</i> Read (holotype)	<i>B. wellingtonensis</i> Read (paratype)	<i>B. wellingtonensis</i> from Chile (this study)
Width of 5th setiger	0.8 mm	1.4 mm	up to 1.4 mm
No. of setigers	60	? (without posterior setigers)	up to 85 setigers
Total length	10 mm	? (without posterior setigers)	up to 18 mm
Length of caruncle		extend to end of setiger 1	extend to end of setiger 1
Notopodium on setiger 1		small but exist	small but exist
No. of hooded hooks on setiger 1	4	7	4–7 (most specimens 4–5)
No. of max. hooded hooks per neuropodium	5	9	9 (most specimens up to 5–7)
Pygidium		? (without posterior end)	4 lobes, dorsal pair smaller than ventral pair
Habitat		organically enriched sand at low tide, making U-shaped sand-grain tube; rock crevices in intertidal pools	making U-shaped burrow in sandstone flat without tubes; making U-shaped sand-grain tube in sand flat
Reference		type specimens (Z.W.1065) (Read, 1975)	type specimens (Z.W.1066) (Read, 1975) this study

Table 4. Morphological characteristics of *Boccardia polybranchia* (Haswell, 1885) from Chile and *B. polybranchia* (Haswell, 1885) from other seas.

	<i>B. polybranchia</i> from Chile	<i>B. polybranchia</i> (Haswell)
Width of 5th setiger	0.6–1.2 mm	?
No. of setigers	38 – (9 out of 10 without posterior setigers)	up to 80 setigers
Total length	5 mm – (9 out of 10 without posterior setigers)	up to 15 mm
Length of caruncle	extend to end of setiger 1	extend to end of setiger 3
Notopodium on setiger 1	small but exist except one (maybe damaged)	small but exist or absent
No. of hooded hooks on setiger 7	4–5	7–8
No. of max. hooded hooks per neuropodium	7	12–13
Pygidium	4 lobes; dorsal pair smaller than ventral pair	4 equal lobes or tubular undivided
Habitat	intertidal	estuarine, sand, rocks on beach, sandy beach, algal zone, intertidal, coraline algae
Reference	specimens (USNM69389) (Blake, 1983)	Blake and Kudennov (1978)

setigers 1–4, white pigmentation on peristomium. Palps crossed by up to 13 white spots in life, white spots disappearing after fixation, only brown color remains along palps. Posterior setigers white. Greenish black fading or disappearing and bright white pigment disappearing from peristomium after fixation.

Prostomium anteriorly deeply incised; caruncle extending to end of setiger 2; occipital tentacle present; eyes absent or present, if present up to four arranged in square, most specimens lack eyes, especially large specimens. Mid-dorsal swelling on setigers 5–6. Branchiae on setigers 2,3,4,-6 and succeeding setigers to posterior end. Branchiae of setigers 2–3 longer than setigers 4 and 6. Setiger 1 with long capillary notosetae and short neurosetae. Bidentate hooded hooks first appear from setiger 7, main fang at right angle to shaft, hooks numbering up to 16 per fascicle.

Setiger 5 modified, bearing two types of heavy spines arranged in two rows: (1) ventral row of spines with expanded tips without bristle, (2) dorsal row of simple, falcate spines without bristle; companion setae absent; only fascicle of winged ventral setae of setiger 5 present. About six ventral spines and five dorsal spines.

Pygidium a fleshy pad, weakly divided.

Habitat and Ecology.—*B. chilensis* inhabited intertidal mud deposits, sand deposits and under coralline algae associated with *D. giardi*. High crawling activity was observed after removal from the shell, and the worm was capable of hiding itself in mud deposits or in the crevices of calcareous substrata. Palp activity was vigorous: fast and strong beating was observed. The species distributed in intertidal zone around Puerto Montt and Chiloé Island but not abundant.

Reproduction and Development.—Egg strings were found in February. All embryos in capsule develop simultaneously without nurse eggs.

Remarks.—The original description of *B. chilensis* from Chile by Blake and Woodwick (1971) and another description by Blake (1983) did not mention its color in live. However, it is easy to distinguish living *B. chilensis* from other species due to its conspicuous markings of black and white on the dorsal surface anteriorly especially around the prostomium, and the white color posteriorly. All specimens have the same relative length branchiae, with slightly longer branchiae on setiger 2 than on setiger 3, which are both longer than those on setigers 4 and 6. It was one of the largest polydorid worms found around Puerto Montt and Chiloé Island.

Distribution.—Peru, Chile, Australia, New Zealand.

Boccardia tricuspa (Hartman, 1939)
(Fig. 2H)

Boccardia tricuspa: Blake, 1983: 249–250.

Morphology of New Materials.—Up to 22 mm long, 0.8 mm wide at setiger 5, for 117 setigers. Weakly dark pigmentation around anterior end of peristomium. Setiger 1 small, with only neuropodia and neurosetae, notopodia absent.

Habitat and Ecology.—*Boccardia tricuspa* inhabited sand deposits in the intertidal zone. It was never extracted from calcareous substrata. It was uncommon in the intertidal zone.

Reproduction.—Unknown.

Remarks.—The specimens from Puerto Montt match the previous morphological descriptions of the specimens from South America (Blake, 1983). Although there is a report

describing *B. tricuspa* as a boring species (Blake, 1983), no worms were extracted from calcareous substrata in Puerto Montt and Chiloé Island.

Distribution.—California, Mexico, Ecuador, Galápagos Islands, Chile.

DISCUSSION

Previous reports identified 12 polydorid species from Chile: *Polydora rickettsi*, *P. bioccipitalis*, *Polydora* sp., *Dipolydora armata*, *D. magellanica*, *D. giardi*, *D. socialis* (all of them formerly described as *Polydora*), *Boccardia polybranchia*, *B. natrix*, *B. chilensis*, *B. tricuspa*, *Carazziella carrascoi* (Blake and Woodwick, 1971; Blake, 1979; 1983; Rozbaczylo, 1985; Basilio et al., 1995). With the three newly found, *Polydora* cf. *rickettsi*, *D. huelma* sp.nov. and *B. wellingtonensis*, the number of polydorids reported along the coast of Chile is now 15 species. Seven species were collected from natural intertidal and aquaculture farming areas within the protected environment around Puerto Montt and Chiloé Island. We did not find *Polydora magellanica* and *Boccardia natrix*, possibly because these two species inhabit southern South America below 53°S (Blake, 1983). Also, we did not find *Polydora bioccipitalis* suggesting that this species inhabits subtropical seas. It is necessary to survey subtidal and deep sea areas of exposed environments to further document the species inhabiting the coast of Chile.

It is well known that only the polydorid species, which show a modification of setiger 5, have the ability to bore in calcareous substrata among the large family Spionidae. The relationships between habitat type and boring activity previously studied in Canadian (Sato-Okoshi and Okoshi, 1997) and Japanese (Sato-Okoshi, 1999, 2000) polydorid species clearly demonstrated that the characteristic of boring activity is species-specific, the boring species never occurring in non-calcareous substrata and vice versa. However, there are some species which are reported from both calcareous and non-calcareous substrata (Blake and Evans, 1973; Read, 1975). It is sometimes difficult to distinguish between boring and non-boring species especially when the non-borer inhabits mud deposits in shell crevices. Careful observation is needed to determine whether the worm inhabits a self-excavated burrow that is completely formed inside the substrate or just inhabits crevices. Adding the present study, it has been shown that: (1) Canadian boring species consisted of two *Polydora*, two *Dipolydora* and one *Boccardia* while non-boring species consisted of one *Polydora*, one *Dipolydora*, one *Boccardiella* and two *Boccardia* (Sato-Okoshi and Okoshi, 1997); (2) Japanese boring species consisted of seven *Polydora*, five *Dipolydora* and one *Carazziella* while non-boring species consisted of one *Polydora*, three *Dipolydora*, one *Carazziella*, one *Boccardiella*, two *Boccardia* and three *Pseudopolydora* (Sato-Okoshi, 1999, 2000); (3) Chilean boring species consisted of one *Polydora* and two *Dipolydora* while non-boring species consisted of one *Dipolydora* and three *Boccardia* (this study). This generic overview shows that the ability to bore into calcareous substrata seems to be widespread among the species of the genera *Polydora* and *Dipolydora*. This hypothesis is interesting from a systematic and evolutionary point of view.

Present study conducted in Chile showed that the boring species exhibited low or non-crawling activity whereas the non-boring species exhibited higher crawling activity and more vigorous palp activity resulted from the observations of both fast and high beating frequency and strong and tough beating action under the still seawater condition. Boring species are considered to be protected by the hosts, suggesting that they are host depen-

dant. Their energetic investment towards excavating burrows in calcareous substrata is higher than that invested in crawling and competition. On the other hand, it appears that fitness of non-boring polydorids would be improved by investing more energy to crawl and compete (Sato-Okoshi, 2000). It is noteworthy to mention that Chilean *D. socialis* inhabited not only mud deposits of a shell but also was found in a self-made shallow groove between the shells (not a complete self-excavated burrow). Consistently, only this non-boring species showed behavioral and morphological characteristics similar to borers (i.e., slow crawler, weakness in palp activity, thin branchial blood vessels). The characteristic of this species has been discussed in previous study suggesting that this is among the species which display a halfway stage of complete differentiation from non-boring to boring strategies (Sato-Okoshi, 2000).

The most abundant boring species were *P. cf. rickettsi* and *D. giardi* both in natural and cultured mollusc shells around Puerto Montt and Chiloé Island. There are some reports that *P. rickettsi* bores into several molluscs in La Serena, the Fourth Region, Chile (Cañete, 1988). *B. wellingtonensis* was the dominant non-boring species inhabiting mud, sand and sandstone intertidal flats around Puerto Montt and Chiloé Island. High abundances of these three species, i.e. two boring species and one non-boring species, were found in Pullinque, Chiloé Island. Our results support that the study of the population dynamics, life history, and interaction among the three species has an intrinsic biological interest, but could also be relevant from the viewpoint of aquaculture. The identification of the settling and boring periods and the life span of the boring species is important in the production of shells from infestation and damage of commercially important molluscs.

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LITERATURE CITED

Basilio, C. D., J. I. Cañete and N. Rozbaczylo. 1995. *Polydora* sp. (Spionidae) un poliqueto perforador de las valvas del ostion *Argopecten purpuratus* (Bivalvia: Pectinidae) en Bahía Tongoy, Chile. Rev. Biol. Mar. Valparaíso 30: 71-77.

Blake, J. A. 1971. Revision of the genus *Polydora* from the east Coast of North America. Smithson. Contr. Zool. 75: 1-32.

_____. 1979. Four new species of *Carazziella* (Polychaeta: Spionidae) from North and South America, with a redescription of two previously described forms. Proc. Biol. Soc. Wash. 92: 466-481.

_____. 1983. Polychaetes of the family Spionidae from South America, Antarctica, and adjacent seas and islands. *Biology of the Antarctic Seas* 14. Ant. Res. Ser. 39: 205–288.

_____. 1996. Family Spionidae Grube, 1850. Pages 81–224 in J. A. Blake, B. Hilbig and P.H. Scott, eds. *Taxonomic atlas of the benthic fauna of the Santa Maria Basin and Western Santa Barbara Channel*, vol.6. Santa Barbara Mus. Nat. Hist., California.

_____. and J. D. Evans. 1973. *Polydora* and related genera (Polychaeta: Spionidae) as borers in mollusk shells and other calcareous substrates. *Veliger* 15: 235–249.

_____. and J. D. Kudenov. 1978. The Spionidae (Polychaeta) from southeastern Australia and adjacent areas, with a revision of the genera. *Mem. Nat. Mus. Victoria* 39: 171–280.

_____. and K. H. Woodwick. 1971. A review of the genus *Boccardia* Carazzie (Polychaeta: Spionidae) with descriptions of two new species. *Bull. So. Calif. Acad. Sci.* 70: 31–42.

Cañete, J. I. 1988. Efectos de *Polydora* en cultivos de pectinídos, con referencia al Ostión del Norte (*Argopecten purpuratus*). Pages 50–60 in H. Flores and J. C. Maureira, eds. Cuarto taller de aquacultura “problemática actual en el cultivo de la ostra Japonesa y Ostión del Norte”, Univ. Católica del Norte, Coquimbo.

Handley, S. J. 1998. Power to the oyster: do spionid-induced blisters affect condition in subtidal oysters? *J. Shellfish Res.* 17: 1093–1099.

Kent, R. M. L. 1979. The influence of heavy infestations of *Polydora ciliata* on the flesh content of *Mytilus edulis*. *J. Mar. Biol. Ass. U.K.* 59: 289–297.

Martin, D. and T. A. Britayev. 1998. Symbiotic polychaetes: review of known species. *Oceanogr. Mar. Biol.* 36: 217–340.

Mesnil, F. 1896. Études de morphologie externe chez les annélides. 1. Les spionidens des côtes de la manche. *Bull. Sci. France Belg.* 29: 110–287.

Mori, K., W. Sato, T. Nomura and M. Imajima. 1985. Infestation of the Japanese Scallop *Patinopecten yessoensis* by the boring polychaetes, *Polydora*, on the Okhotsk Sea Coast of Hokkaido, especially in Abashiri Waters. *Bull. Jap. Soc. Sci. Fish.* 51: 371–380. (in Japanese with English abstract)

Okoshi, K. and W. Sato-Okoshi. 1996. Biominerization in molluscan aquaculture—growth and disease. *Bull. Inst. Océanogr. Monaco* 14: 151–169.

Read, G. B. 1975. Systematics and biology of Polydorid species (Polychaeta: Spionidae) from Wellington Harbour. *J. Royal Soc., New Zealand*. 5: 395–419.

Rozbaczylo, N. 1985. Los anélidos poliquetos de Chile. Índice sinónimico y distribución geográfica de especies. *Monografías Biológicas*, Pontificia Univ. Católica de Chile, Santiago, Chile. 3: 1–284.

Sato-Okoshi, W. 1999. Polydorid species (Polychaeta, Spionidae) in Japan, with descriptions of morphology, ecology and burrow structure 1. Boring species. *J. Mar. Biol. Ass. U.K.* 79: 831–848.

_____. 2000. Polydorid species (Polychaeta, Spionidae) in Japan, with descriptions of morphology, ecology and burrow structure 2. Non-boring species. *J. Mar. Biol. Ass. U.K.* 80: 443–456.

_____. and K. Okoshi. 1997. Survey of the genera *Polydora*, *Boccardiella* and *Boccardia* (Polychaeta, Spionidae) in Barkley Sound (Vancouver Island, Canada), with special reference to boring activity. *Bull. Mar. Sci.* 60: 482–493.

Woodwick, K. H. 1961. *Polydora rickettsi*, a new species of spionid polychaete from lower California. *Pac. Sci.* 15: 78–81.

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ADDRESSES: (W.S.-O.) *Laboratory of Aquatic Ecology, Division of Environmental Bioremediation, Graduate School of Agricultural Science, Tohoku University, Sendai 981-8555, Japan.* (M.T.) *Japan International Cooperation Agency-Chile, Project of Developing Benthic Aquaculture Resources, Ca. Chinquihue Km 12, Puerto Montt, Chile.* CORRESPONDING AUTHOR: (W.S.-O.) *E-mail: <wsokoshi@bios.tohoku.ac.jp>*